STREAMFLOW WATER QUALITY IN THE GEORGIA COASTAL PLAIN

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REFERENCE: Proceedings of the 1989 Georgia Water Resources Conference, held May 16 and 17, 1989, at The University of Georgia. Kathryn J. Hatcher, Editor, Institute of Natural Resources, The University of Georgia, Athens, Georgia, 1989.

ABSTRACT

Studies were conducted in the Georgia Coastal Plain on cropped and forested watersheds ranging in size from 16.7 km^2 to 334 km^2 to determine dissolved solids and suspended sediment concentrations and loads. Observed suspended sediment concentrations in streamflow from these watersheds were quite low, averaging about 15 mg/L. Dissolved solids concentrations were much greater, averaging five times the mean suspended sediment concentration; thus dissolved solids are the primary component of total solids in these stream systems. Suspended sediment concentrations increased with increasing instantaneous discharge rates. Loads of both dissolved solids and suspended sediment were primarily a function of flow volume. Low suspended sediment concentrations and loads in Georgia Coastal Plain streamflow (as compared to streamflow in other physiographic regions) can be attributed to deposition of materials moving from upland areas into the broad, flat, heavily-vegetated, low-gradient drainage systems.

INTRODUCTION

Concentrations and loads of dissolved solids and suspended sediment in streamflow are a measure of soil erosion, and if excessive, may result in undesirable water quality. Many studies have closely linked concentrations and loads of both components to land use practices (Dendy and Bolton, 1976; Costa, 1977; Dragoun and Miller, 1966; Ostry, 1982). In the past, agricultural practices which inadequately protected the soil surface resulted in serious erosion. Soil conservationists and farmers have greatly reduced erosion rates through conservation methods such as strip cropping, terracing, farming on the contour, and using grassed waterways. Other anthropogenic activities that adversely impact water quality include forestry operations which clearcut the land, rural unpaved roads, road maintenance operations, and construction projects.

The USDA-ARS Southeast Watershed Research Laboratory (SEWRL) has conducted several studies on total solids, dissolved solids, and suspended sediment concentrations and loads in streamflow, and on soil erosion in the Tifton Upland area of the Georgia Coastal Plain. This paper presents an overview of the results of these studies as they relate to surface-water quality in the Georgia Coastal Plain.

LOCATION AND DESCRIPTION OF THE STUDY AREA

The study area is comprised of the Little River Watershed (LRW) and is located in the Tifton Upland District of the Georgia Coastal Plain province (Figure 1). The Little River headwaters near Ashburn, Georgia, and flows generally southward through south Georgia until merging with the Withlacoochee River near Valdosta, Georgia.

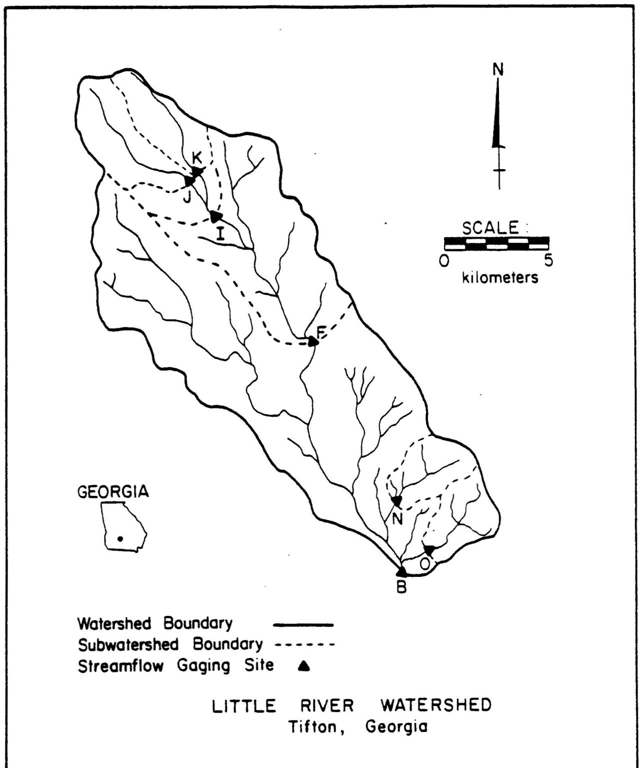

Figure 1. Map of Little River watershed and gaged subwatersheds.

Concentrations and loads of dissolved solids and suspended sediment in streamflow in the

Georgia Coastal Plain are an integration of landscape features, soils, land use, and rainfall. The Coastal Plain of Georgia is generally flat or slightly rolling. Upland areas gently slope to broad, alluvial floodplains adjacent to the streams. The elevation of the upland areas may be only 3-6 m higher than that of the floodplains. Surface soils of the Georgia Coastal Plain range in texture from sand to sandy clay loam, and in general, are highly weathered and low in organic matter. Underlying subsoils and geologic materials range from deep sands to clayey materials that are very slowly permeable. Land use in the upland areas is predominantly agricultural. Cropland, forest, and pasture comprise most of the upland landscape. Floodplains are heavily vegetated with both tree and shrub species. The annual pattern of precipitation consists of relatively uniform monthly rainfall distribution from December through June, higher monthly rainfall in July and August, and lower monthly rainfall from September through November. The mean annual precipitation is about 120 cm.

MATERIALS AND METHODS

Streamflow, rainfall, and water-quality monitoring stations were installed at 7 locations on the LRW beginning in 1966. The gaging stations sample streamflow from a nested series of watersheds beginning with subwatersheds K and J (~16.7 and 22.1 km^2, respectively) near Ashburn, and ending with watershed B (~334 km^2) near Tifton (Figure 1). The stream stage is automatically recorded at 5 minute intervals at each station. A network of raingages over the watershed also provides precipitation data at 5 minute intervals. Water samples for solids and sediment analyses were collected by automatic samplers at stations J, K, N, and O. Weekly grab samples were collected from all remaining stations by sampling from flow over the weir. Selected high flow events were sampled at stations B, F, and K using depth-integrating sampling equipment.

Analyses of water for total solids, dissolved solids, or suspended sediment has been done by several methods. A study conducted from 1974-78 examined total solids by evaporating water samples to dryness and weighing the residue. For this study, the fraction of total solids greater than 125 μm in diameter was determined by screening. Concentrations of suspended sediment for a 1979-81 study were determined by centrifugation, decantation of supernatent, and evaporation of residue to dryness. More recent work (1984-86) separated total solids into the dissolved and suspended fractions using suction filtration through 0.45 μm filters.

RESULTS

Concentrations and loads of dissolved and suspended components of streamflow were examined according to ranges, mean values, and relationships with hydrologic patterns. For the 4-year record period beginning in 1974, total solids concentrations for all stations averaged 96 mg/L, and the maximum observed concentration was 859 mg/L (Sheridan and Hubbard, 1987). For seasonal analyses, record periods were established relative to the hydrologic seasons March-May, June-August, September-November, and December-February. Total solids concentrations were found to be significantly lower for March-May and for December-February, than for June-August and September-November (Table 1). This variation in concentrations relative to hydrologic season can be explained by unit-area runoff. The March-May and December-February months had the greatest unit-area runoff and the lowest total solids concentrations. This implies that increased rainfall and runoff during this period resulted in dilution of total solids transported by streamflow. The mean monthly total solids load for 1974-78 was 26.7 kg/ha. Correlation analyses showed that runoff volume was the best predictor of total solids load.

TABLE 1. Mean Total Solids and Suspended Sediment Concentrations in Runoff, by Seasons.

Season	Mean total solids concentration*	Mean suspended sediment concentration**
	------------ mg L^{-1}	------------
Mar-May	86b***	17a***
June-Aug	107a	16a
Sept-Nov	111a	10b
Dec-Feb	85b	13b

*(1974-1978).
**(1979-1981).
***Values followed by the same letter are not significantly different at the 5% level for Duncan's multiple range test. (From Sheridan and Hubbard, 1987)

Suspended sediment concentrations were measured and loads were calculated in separate studies in 1978-81, and again in 1984-86. The mean suspended sediment concentration from both periods was 15 mg/L. Suspended sediment concentrations increased with flow rate and also tended to be higher during the period of the year when agricultural activity was greatest. For 1979-81 the maximum monthly suspended sediment load was 70.8 kg/ha, while for 1984-86 the maximum was 37 kg/ha. Correlation analyses showed that runoff volume was also the best predictor of suspended sediment load.

Dissolved solids concentrations were measured directly during the 1984-86 study. Concentrations ranged from 19 to 159 mg/L, with a mean of 60 mg/L. Dissolved solids concentrations can be estimated indirectly for the 1974-78 period. Subtraction of the mean suspended sediment value of 15 mg/L (found for both the 1979-81 and 1984-86 record periods) from the mean 1974-78 total solids concentration of 96 mg/L yields a mean dissolved solids concentration of 81 mg/L. The conclusion reached from both of these studies on solids concentrations and loads is that the dissolved fraction is the primary component of total solids transported in Coastal Plain streamflow. As with total solids and suspended sediment, runoff volume was the best predictor for dissolved solids load.

One additional method of examining erosion and sediment concentrations in streamflow is through the use of sediment-delivery ratios, which compare observed and predicted sediment movement. Using information from one subwatershed, Sheridan et al. (1982) compared actual erosion, as based on measured total sediment in streamflow, with erosion predicted by the Universal Soil Loss Equation (USLE). The USLE was utilized to estimate gross soil movement for all land uses within the watershed including forest and pasture. The computed monthly total sediment (suspended sediment + dissolved solids) delivery ratio varied from 0.2 percent to 44.6 percent for the study period (Table 2). For all months, the estimated erosion by the USLE was far greater than the measured sediment yield. These results indicate that application of the traditional annual-based, sediment-delivery ratio to predict sediment yields on a storm, or short-term, basis would cause significant errors in estimating the quantity of sediment transported from Coastal Plain areas. Computed sediment-delivery ratios were observed to vary seasonally. Actual sediment in streamflow was much lower than that predicted by the USLE for the June-August and September-November periods than for the March-May and December-February periods.

DISCUSSION

Studies on the LRW show that dissolved solids are the primary component of total solids concentrations and loads in streamflow from Georgia Coastal Plain watersheds. The ratio of suspended sediment to dissolved solids in streamflow is about 0.2. This ratio is quite low, but within the reported global limits that range from greater than 100 to less than 0.05 (Walling and Webb, 1983). Dissolved solids are the primary component of total solids transported in Coastal Plain streams; however, this is not a result of high dissolved solids concentrations (estimated load of 26 Mg/km^2/yr for LRW versus 39 Mg/km/yr global data set mean), but because observed suspended sediment concentrations are extremely low. The observed higher dissolved solids than suspended sediment concentrations and loads for these Coastal Plain watersheds are the reverse of that found in many other stream and river systems. Walling and Webb (1983) reported that in over 60 percent of the 490 rivers they studied, particulate load exceeded the dissolved component.

The observed low concentrations of suspended sediment in these Coastal Plain systems and the low sediment delivery ratios can be explained by characteristics of Coastal Plain watershed drainage and transport systems. First, surface runoff volumes from upland areas are relatively low, and baseflow or delayed subsurface flow may account for as much as 60 to 80 percent of the total annual runoff (Knisel and Sheridan, 1983; Hubbard and Sheridan, 1983; Shirmohammadi et al., 1984). Groundwater entering streams does not carry suspended sediment, but does contain dissolved ions. Second, the floodplains are densely vegetated and may be covered with water for considerable periods of time following rainfall/runoff events. In effect, these alluvial zones act as settling basins where sediment transported from upland areas may be

TABLE 2. Monthly Sediment Delivery Ratios, Station K, Little River Watershed, 1974-76.

Year	Month	Measured Total sediment yield, MT	USLE estimated erosion, MT	Sediment delivery ratio, percent
1974	09	36.1	440.0	8.2
	10	1.3	52.9	2.5
	11	0.5	237.2	0.2
	12	6.1	70.1	8.7
1975	01	34.5	394.5	8.7
	02	55.1	123.5	44.6
	03	95.8	1342.4	7.1
	04	99.8	925.1	10.8
	05	48.1	693.0	6.9
	06	16.2	460.5	3.5
	07	37.0	1495.5	2.5
	08	49.7	3934.5	1.3
	09	0.6	39.2	1.5
	10	0.6	348.3	0.2
	11	0.3	198.1	0.2
	12	4.7	152.6	3.1
1976	01	53.5	568.2	9.4
	02	77.5	228.4	33.9
	03	95.6	485.5	19.7
	04	13.9	310.6	4.5
	05	195.1	4646.0	4.2
	06	16.7	296.1	5.6
	07	29.8	1075.8	2.8
	08	37.6	1953.5	1.9
	09	33.6	806.9	4.2
	10	26.6	402.5	6.6
	11	41.6	1401.9	3.0
	12	57.6	156.0	36.9

(From Sheridan et. al., 1982)

deposited. These areas comprise 20 to 25 percent of the total LRW area and have little potential for detachment of sediment by rainfall. Third, the cross-section of the channel/floodplains is such that as streamflow increases, the stream spreads over broad, flat, floodplain areas; further enhancing the likelihood of sediment deposition. Due to the heavy vegetation and flat cross-sections, effective flow velocities may not increase substantially with increasing flow stage. Hence, erosion occurring from agricultural fields may not be appearing in the streamflow due to the role of the floodplain as a depositional area. Lowrance et al. (1986) examined sediment deposition on these same Coastal Plain watersheds and estimated a long-term annual rate of sediment deposition of 35 to 52 Mg/ha/yr. They concluded that the Coastal Plain alluvial floodplains are important sinks for sediments.

Results of studies on dissolved solids and suspended sediment in streamflow from watersheds in the Georgia Coastal Plain show that water quality relative to these parameters is generally good. The low levels of suspended sediment and low-sediment delivery ratios imply that erosion control currently used by landowners on these watersheds is, in general, effective. However, the characteristics of the Coastal Plain landscape and alluvial floodplain zones make this conclusion tentative. Research at the SEWRL has shown that soil eroded from upland areas during major rainfall/runoff events is largely deposited in the floodplain and is not being transported in the streams. The landscape of the Georgia Coastal Plain is quite different than many other physiographic regions because of its low gradient and broad floodplains, which result in virtually all draining waters flowing over flat depositional areas during some part of their route from agricultural field to streams. Hence, the general good quality of surface-water resources in the Georgia Coastal Plain province relative to dissolved solids and suspended sediment does not imply that soil conservation measures should be less emphasized or reduced, because most eroded materials are simply being deposited in floodplain and riparian zones. Any lessening of soil conservation awareness and practices on upland areas of Coastal Plain watersheds would result both in increased soil erosion, with its deleterious effect on potential for growing crops or trees, and accelerated rates of sediment accumulation in floodplain areas.

LITERATURE CITED

Costa, J. E., 1977. Sediment Concentration and Duration in Stream Channels. J. Soil Water Conserv. 32:168-170.

Dendy, F. E., and G. C. Bolton, 1976. Sediment Yield-Runoff-Drainage Area Relationships in the United States. J. Soil Water Conserv. 31: 264-266.

Dragoun, F. J., and C. R. Miller, 1966. Sediment Characteristics of Two Small Agricultural Watersheds. Trans. ASAE 9:66-70.

Hubbard, R. K., and J. M. Sheridan, 1983. Water and Nitrate-Nitrogen Losses from a Small, Upland Coastal Plain Watershed. J. Environ. Qual. 12:291-295.

Hubbard, R. K., J. M. Sheridan, and L. R. Marti, 1989. Transport of Dissolved and Suspended Sediment in Coastal Plain Watersheds. (In Preparation).

Knisel, W. G., and J. M. Sheridan, 1983. Procedure for characterizing hydrologic processes in the Coastal Plain of the Southeastern United States, p. 193-210. In M. C. Fuschini Mejia (ed.) Proc. UNESCO-CONAPHI Int. Program (IHP), Hydrology Large Flatlands, Buenos Aires, Argentina. 11-20 April. UNESCO, Paris.

Lowrance, R., J. K. Sharpe, and J. M. Sheridan, 1986. Long-term Sediment Deposition in the Riparian Zone of a Coastal Plain Watershed. J. Soil and Water Conserv. 41:266-271.

Ostry, R. C., 1982. Relationship of water quality and pollutant loads to land uses in adjoining watersheds. Water Res. Bull. 18:99-104.

Sheridan, J. M., C. V. Booram, Jr., and L. E. Asmussen, 1982. Sediment-Delivery Ratios for a Small Coastal Plain Agricultural Watershed. Trans. ASAE 25:610-615 & 562.

Sheridan, J. M., and R. K. Hubbard, 1987. Transport of Solids in Streamflow from Coastal Plain Watersheds. J. Environ. Qual. 16: 131-136.

Shirmohammadi, A., W. G. Knisel, and J. M. Sheridan. 1984. An approximate method for partitioning daily streamflow data. J. Hydrol. 74:335-354.

Walling, D. E. and D. W. Webb, 1983. The Dissolved Loads of Rivers: A Global Overview. P. 3-20. In Dissolved Loads of Rivers and Surface Water Quantity/Quality Relationships. IAHS Pub. No. 141. International Association of Hydrological Sciences, Washington, DC.